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(57) Apparatus for harnessing tidal or wave power comprises an underwater base structure 1 anchored to the sea bed and a floating structure 5 connected to the base structure 1. A pair of variable volume bags *a*, *b* is trapped between relatively movable components of the base and floating structures. The bags *a*, *b* expand and compress as a result of movement of the floating structure 5 due to tidal or wave motion. The bags *a*, *b* have valve controlled inlet and outlet means such that expansion of a bag causes it to fill with sea water and compression of a bag causes it to expel the water which thereafter is used to generate usable energy (e.g. by driving a turbine). Alternative arrangements utilising a multiplicity of bags are disclosed (Figs. 2 to 4) and the apparatus may utilise a lever arrangement to effect expansion and compression of the bags (Fig. 5).

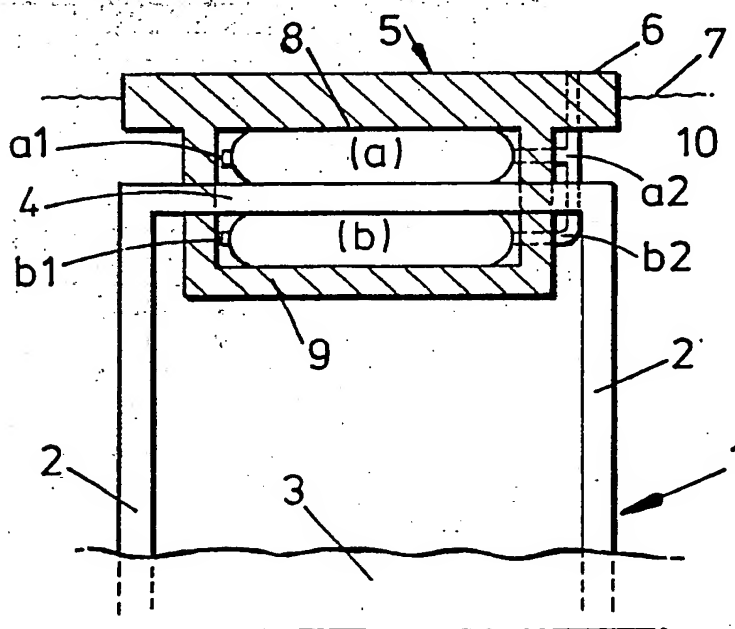


FIG. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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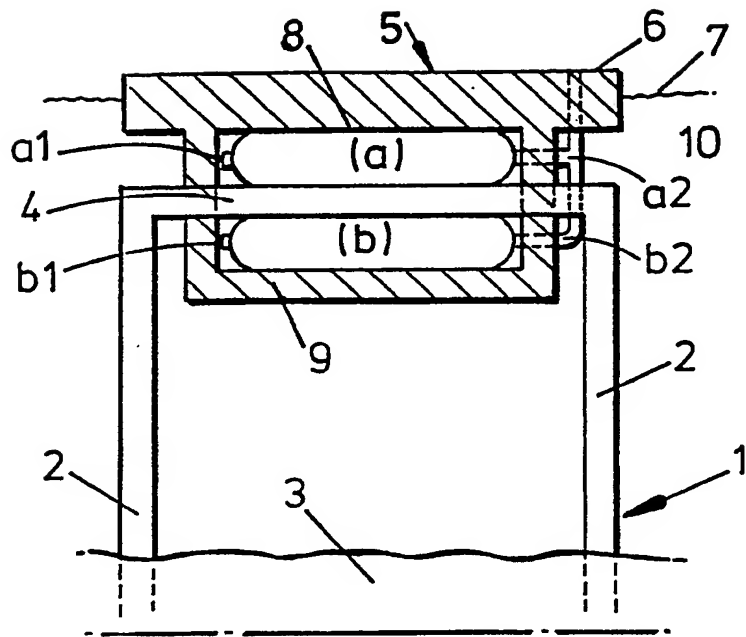


FIG. 1

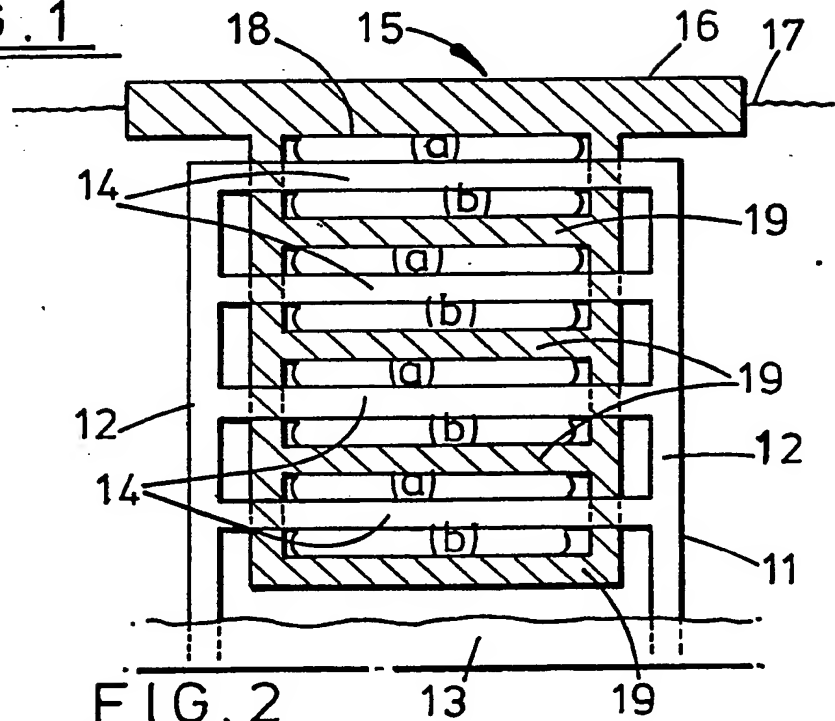
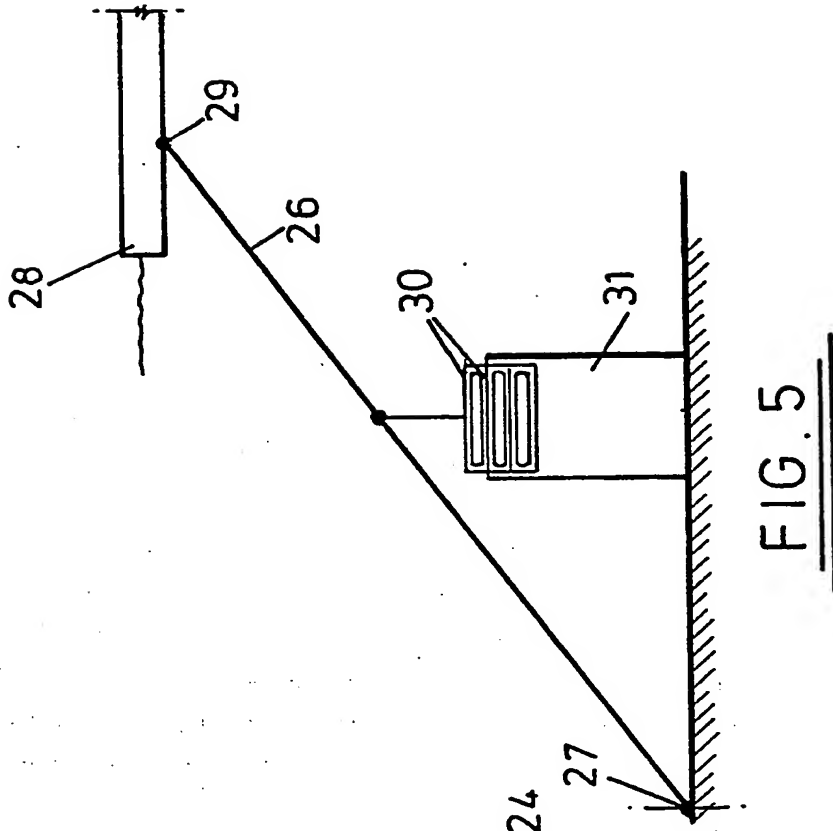
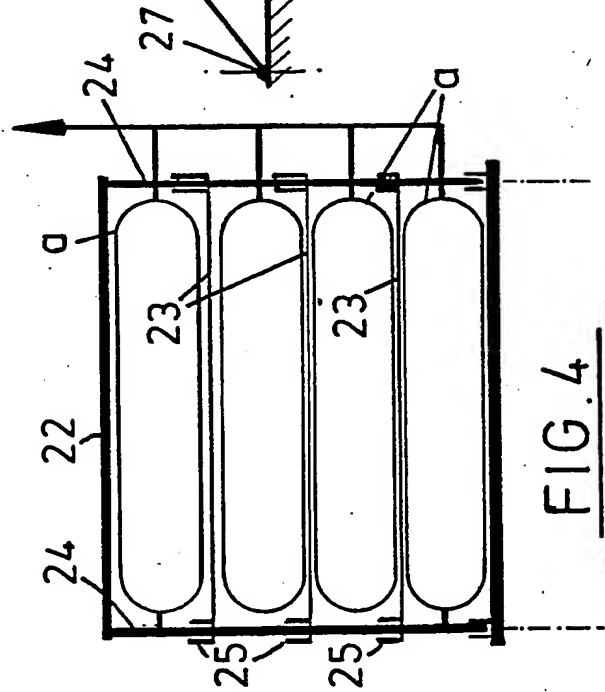
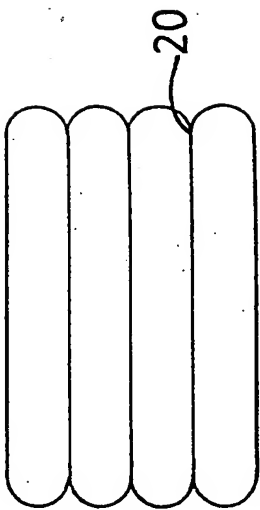


FIG. 2



APPARATUS FOR HARNESSING TIDAL POWER

This invention relates to apparatus for harnessing tidal or wave power.

Many different methods and devices have been proposed for converting the work done by the rise and fall of the tide, or of the movement of waves on a body of water, into useable power. A number of these are based on the idea of harnessing the available energy to drive some form of pump, normally a water pump which pumps water from the body of water from which the energy is obtained. The water thus pumped may be directly used to drive a turbine or pumped up to a relatively high level reservoir from which it may be used to generate power according to known methods.

An example of apparatus of this general type is disclosed in British Patent No. 2 007 314B. This document discloses an apparatus for harnessing wave power comprising a tube suspended between a floating raft and a base anchored to the water bed. The tube is wound with a helical spring and forms an elongate bellows which changes its volume as it extends or contracts as the raft rises and falls with wave motion. As the raft rises, the tube is stretched (against the action of the spring) and expanded with the result that water enters the tube through a non-return valve. As the raft falls the spring contracts the tube, reducing its volume and expelling the water through a second non-return valve.

British Patent No. 2 002 052B discloses further apparatus for harnessing wave energy which employ at least one variable volume pressure chamber, having valve controlled inlet and outlet means, for pumping sea water. Three different structures are described, each of which has a tube wound with a helical coil as the pressure chamber. In one of these arrangements the tube is suspended between a float and an anchored base such that the volume of the tube decreases as the float rises, the helical spring constricting the tube as it extends and twists, and vice-versa. In another arrangement the tube is alternately twisted and untwisted by the movement of a hinged raft which floats in the water with the axis about which it hinges lying substantially vertical. In the third structure a number of tubes are supported horizontally between arms of a similar hinged raft.

Movement of the arms alternately extends the tubes to reduce their volume and allows them to relax and increase their volume.

It is an object of the present invention to provide an improved apparatus for harnessing tidal or wave power.

According to a first aspect of the present invention there is provided apparatus for harnessing tidal or wave power, comprising a base structure adapted to be anchored to the sea bed, a floating structure connected to said base structure, at least one variable volume bag trapped between relatively movable components of said structures and cooperative with said structures so as to expand or compress as a result of movement of the floating structure due to tidal or wave motion, and valve controlled inlet and outlet means for the bag, whereby expansion of the bag causes it to fill with sea water and compression of the bag causes it to expel the water which thereafter is used to generate usable energy.

The invention thus provides a water pump powered by the rise and fall of the tide or wave motion with which a sufficient head of water can be provided to drive electricity generating equipment efficiently. The use of variable volume bags for pressure chambers provides an advantageously simple and sturdy structure which allows construction to the relatively large scale necessary for harnessing tidal power.

The bag, which is preferably made of impervious synthetic plastics material but may be made of any other suitable material, may be secured to these components, as for example by adhesive, for movement therewith. Alternatively the bag may have air pockets in an upper wall thereof so as to maintain contact with the upper component and, additionally, the bag may have a weighted bottom wall to maintain contact with the lower component.

According to a second aspect of the present invention there is provided apparatus for harnessing tidal power, comprising a base structure adapted to be anchored to the sea bed, a floating structure connected to said base structure, a pair of variable volume pressure chambers disposed between relatively movable components of said structures and cooperative with said structures so as to expand or compress as a result of movement of the floating structure due to tidal or wave motion, one pressure chamber being arranged above the

moving component of the floating structure and the other pressure chamber being arranged below said moving component such that the two pressure chambers expand out of phase with each other, and valve controlled inlet and outlet means for each pressure chamber, whereby expansion of each pressure chamber causes it to fill with sea water and compression of each pressure chamber causes it to expel the water which thereafter is used to generate usable energy.

One pressure chamber thus expels water as the floating structure rises and the other pressure chamber expels water as the floating structure falls. Water is therefore pumped from the apparatus regardless of whether the floating structure is rising or falling.

Advantageously, a plurality of said pairs of pressure chambers is provided in vertical array. Thus a more compact structure is obtained allowing smaller and more manageable bags to be used.

Preferably the pressure chambers comprise variable volume bags as above.

A plurality of bags may be disposed between each pair of said relatively moveable components of the floating and base structures, said bags separated from one and other by partition plates which prevent uneven compression of the bags. Large tidal ranges can thus be accommodated using relatively thin bags.

Preferably the partition plates are slidably mounted on rods which maintain them in a substantially horizontal plane.

Preferably spacer members are provided between adjacent pairs of partition plates to maintain a minimum separation of the plates.

The floating structure may include a floating surface island which may be of large area and carry an electricity generating plant. In addition, for safety reasons, the floating structure may include a sub-surface platform serving as a top pressure plate at a level beneath the surface which is unaffected by surface conditions and storm effects.

In one embodiment of the invention a lever arm is pivotally secured at its first end to the surface island and at its second end to a point below the surface of the sea, for instance on the sea bed, the said relatively moveable components of the floating structure being pivotally secured to the lever arm at a point intermediate its ends, the arrangement being such that the range of movement of the

moveable components is less than the range of movement of the floating island.

In each of the above discussed embodiments of the invention the bags may be reinforced against geometric distortion by the provision of girdles which strengthen the sides of the bag. The girdles may, for instance, be formed from a fabric cord.

Preferably the apparatus of the invention is duplicated at different sites one of which is experiencing high or low tide while the other is experiencing mid-tide thus creating reasonably constant power generation.

The invention will now be further described by way of example only, with reference to the accompanying drawings, in which:-

Fig. 1 is a diagrammatic side view of a simple embodiment of the invention;

Fig. 2 is a corresponding view of a second embodiment with parts removed for the sake of clarity;

Fig. 3 illustrates a modified component of the embodiments of the invention shown in Figs. 1, 2, 4 and 5;

Fig. 4 is a diagrammatic side view of part of a third embodiment of the invention; and

Fig. 5 is a diagrammatic side view of a fourth embodiment of the invention.

Referring now to the drawings, Fig. 1 shows a simplified construction of the apparatus in accordance with the invention for harnessing tidal power. The illustrated apparatus has an underwater fixed base structure 1 with sufficient, e.g. four, vertical legs 2 (only two shown) anchored in the sea bed 3. The legs 2 support a pressure plate 4 disposed between upper (a) and lower (b) bags carried by a floating structure 5 including a surface island 6 projecting above the sea level 7 and an underwater portion slidably received in the base structure 1 so as to move vertically relatively thereto as the tide rises and falls. It will be appreciated that the relative sizes of the surface island 6 and the bags will, in most practical applications, be considerably different from that illustrated diagrammatically in the drawings. The floating structure 5 has pressure plates 8, 9 which cooperate with the pressure plate 4 of the base structure 1 to define variable volume spaces occupied by the bags a, b. As the sea level 7

falls with an ebb tide the upper bag a is compressed and the lower bag b can expand. Conversely, when the sea level 7 rises the upper bag a can expand and the lower bag b is compressed. The spacing between the fixed pressure plate 4 and the movable pressure plates 8, 9 is sufficient to accommodate the maximum anticipated tidal variation while maintaining adequate clearance between the fixed and movable pressure plates.

Each bag a, b is made of heavy duty impervious synthetic plastics sheet material and has a water inlet a1, b1 controlled by a non-return valve (not shown) at one end. At the other end the bag a, b has an outlet pipe a2, b2 connected to a collecting pipe 10 for delivering water to the surface of the island 6. Return flow of water into the bags a, b from the collecting pipe 10 is prevented by non-return valving which may be provided either in the bag outlets or in the collecting pipe 10.

The lower surface of the bag a and the upper surface of the bag b are held in contact with adjacent sides of the fixed pressure plate 4 by adhesive or other suitable means. Each bag a, b may for example have its upper wall provided with air pockets or tubes so that it floats into contact with the pressure plate thereabove. The lower wall of each bag a, b may be weighted, as by pockets or tubes filled with clay paste, sand or other dense material, to maintain contact with the pressure plate immediately therebelow.

In operation of the Fig. 1 embodiment, the floating structure 5 moves up and down with the tidally varying sea level 7 to alternately compress and expand the bags a, b. During expansion each bag a, b draws in water through its inlet a1, b1 and on compression the water is expelled through the outlet pipe a2, b2 into the collecting pipe 10.

It will thus be seen that the apparatus is an efficient water pump driven by the movement of the floating structure 5. Water is pumped through the pipe 10 under high pressure and may either be supplied directly to electric power generating turbines (not shown) or accelerated further at the surface before being fed to the turbines. (The stream of water in the collecting pipe 10 may be accelerated at the surface before being supplied to electric power generating turbines forming part of electricity generating plant (not shown)

supported by the island 6.) The turbines form part of an electricity generating plant (not shown) supported by the island.

Alternatively, the water supply may be used in other ways well known to the person skilled in the art for generating power. For example the water is pumped through the pipe 10 under sufficiently high pressure for it to be supplied to an elevated reservoir which can be used to generate hydroelectric power.

In the embodiment of Fig. 2 like components are given the same reference numerals increased by 10 and are not further described. The bags a, b are indicated in outline but their inlet and outlet connections and the collecting pipe have been omitted for the sake of clarity. The construction of the embodiment of Fig. 2 is similar to that of Fig. 1 save that multiple pairs of bags a, b are provided between respective upper and lower pressure plates 14, 18 and 19 with the upper bag a of each pair trapped between a fixed lower pressure plate 14 and a movable upper pressure plate 18 or 19, and the lower bag b of each pair being trapped between an upper pressure plate 14 and a lower pressure plate 19. The base structure 11 and the floating structure 15 thus each have multiple, vertically spaced pressure plates which cooperate to alternately expand and compress the bags a, b of each pair in the way already described in relation to the embodiment of Fig. 1.

The embodiment of Figure 2 enables a much greater volume of water to be pumped with each rise or fall of the tide than with the embodiment of Figure 1 without increasing the size of the individual bags. This is desirable as smaller bags will be structurally stronger and less susceptible to geometric distortion which tends to reduce efficiency. The result is an advantageously compact structure which utilises relatively small bags.

For maximum efficiency the bags should be shaped so that they enable the highest proportion of their water capacity to be pumped, without losses due to geometric distortion. The thickness of the bags should therefore be the minimum possible to accommodate the tidal range with a reasonable safety margin. It is proposed that flat circular bags with a diameter:thickness ratio of in excess of 6:1 will give acceptable results. For instance, the bags could have a diameter of 10m and a thickness of 1.5m.

Figure 3 illustrates a modified bag which may be used to reduce geometric distortion where circumstances, such as a large tidal range, dictate that bags of a relatively large thickness must be used. The bag is reinforced with girdles 20, which may be formed from cord or other suitable material, which strengthen the side walls of the bag and thus limit distortion.

Alternatively the variable volume spaces defined between each pair of pressure plates of the floating structure 5 and the base structure 1 could be filled with two or more relatively thin bags. Such an arrangement is illustrated diagrammatically in Figure 4. Four relatively thin bags a are disposed between pressure plates 21 and 22. Adjacent bags a are separated by partition plates 23 slidably mounted on rods 24 to prevent uneven compression of the bags. The partition plates 23 and the pressure plate 22 have spacers 25 positioned at their edges which prevent any of bags a being squashed flat which might otherwise damage the bags.

It will be understood that bags of the type shown in Figure 3 and/or the arrangement of Figure 4, may be used with the embodiments of Figs. 1, 2 and 5 if desired.

A further embodiment of the present invention which enables the use of relatively thin bags where there is a large tidal range is illustrated in Figure 5. A lever arm 26 is pivotally connected to the sea bed at one end 27 and is pivotally secured to a floating structure 28 at the other end 29. Moving pressure plates 30 are secured to the lever arm at a point intermediate its ends 27 and 29 and cooperates with a base structure 31 and bags a and b. Through this arrangement the movement of the moving pressure plates 30 will be less than the rise and fall of the tide, thus the minimum thickness of the bags is not dictated by the tidal range.

The above embodiments of the invention have been described in relation to the harnessing of tidal power. The various structures are particularly suited for the large scale construction required for the effective harnessing of the slow movement of the tide. The power generated is proportional to the area of the island and both the rate and range of the tidal movement. Given the slow rate of rise and fall of the tide large islands are required to generate a worthwhile amount of usable power. The relatively simple and robust structure of the

present invention facilitates the required large scale construction. For instance, islands of in excess of  $1000\text{m}^2$  are envisaged.

However, it will be appreciated that the above described structures could be scaled down to a size suitable for harnessing wave energy. The reduction in amount of available energy consequential upon the necessary reduction in size of the island will be compensated for by the increased frequency of rise and fall of the island.

CLAIMS:

1. Apparatus for harnessing tidal or wave power, comprising a base structure adapted to be anchored to the sea bed, a floating structure connected to said base structure, at least one variable volume bag trapped between relatively movable components of said structures and cooperative with said structures so as to expand or compress as a result of movement of the floating structure due to tidal or wave motion, and valve controlled inlet and outlet means for the bag, whereby expansion of the bag causes it to fill with sea water and compression of the bag causes it to expel the water which thereafter is used to generate usable energy.
2. Apparatus according to claim 1, wherein the bag is secured to said components for movement therewith.
3. Apparatus according to claim 1, wherein the bag has air pockets in an upper wall thereof so as to maintain contact with the upper component.
4. Apparatus according to claim 1, wherein the bag has a weighted bottom wall to maintain contact with the lower component.
5. Apparatus according to any preceding claim, wherein a pair of said bags is provided and one bag is arranged above the moving component of the floating structure and the other bag is arranged below said moving component, whereby the two bags expand and compress out of phase with each other.
6. Apparatus according to claim 5, wherein a plurality of said pairs of bags is provided in vertical array.
7. Apparatus for harnessing tidal or wave power, comprising a base structure adapted to be anchored to the sea bed, a floating structure connected to said base structure, a pair of variable volume pressure chambers disposed between relatively movable components of said structures and cooperative with said structures so as to expand or compress as a result of tidal movement of the floating structure, one pressure chamber being arranged above the moving component of the floating structure and the other pressure chamber being arranged below said moving component such that the two pressure chambers expand out of phase with each other, and valve controlled inlet and outlet means for each pressure chamber, whereby expansion of each

pressure chamber causes it to fill with sea water and compression of each pressure chamber causes it to expel the water into the collection means.

8. Apparatus as claimed in claim 7, wherein a plurality of said pairs of pressure chambers is provided in vertical array.

9. Apparatus according to any preceding claim, wherein there is a plurality of variable volume bags disposed between each pair of said relatively moveable components of the floating and base structures, said bags separated from one and other by partition plates which prevent uneven compression of the bags.

10. Apparatus according to claim 9, wherein the partition plates are slidably mounted on rods which maintain them in a substantially horizontal plane.

11. Apparatus according to claim 9 or 10, wherein spacer members are provided between adjacent pairs of partition plates to maintain a minimum separation of the plates.

12. Apparatus according to any preceding claim, wherein the floating structure includes a floating surface island.

13. Apparatus according to claim 12, wherein the floating structure includes a sub-surface platform serving as a top pressure plate at a level beneath the surface which is unaffected by surface conditions and storm effects.

14. Apparatus according to claim 12 or 13, wherein the floating island is of large surface area and carries an electricity generating plant.

15. Apparatus according to any one of claims 12 to 14, wherein a lever arm is pivotally secured at its first end to the surface island and at its second end to a point below the surface of the sea, the said relatively moveable components of the floating structure being pivotally secured to the lever arm at a point intermediate its ends, the arrangement being such that the range of movement of the moveable components is less than the range of movement of the floating island.

16. Apparatus according to claim 15, wherein the first end of the lever arm is secured to the sea bed.

17. Apparatus according to any one of claims 1 to 6 and 9 to 16, wherein the bags are made from impervious synthetic plastics material.

18. Apparatus according to any one of claims 1 to 6 and 9 to 16, wherein each bag is reinforced against geometric distortion by the provision of girdles which strengthen the sides of the bag.

19. Apparatus according to claim 18, wherein the girdles are formed from a fabric cord.

20. Apparatus according to any preceding claim, when duplicated at different sites one of which is experiencing high or low tide while the other is experiencing mid-tide thus creating reasonably constant power generation.

21. Apparatus for harnessing tidal or wave power, substantially as hereinbefore described with reference to the accompanying drawings.

Patents Act 1977  
Examiner's report to the Comptroller under  
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Application number  
GB 9221386.7

Relevant Technical fields

(i) UK Cl (Edition L ) F1S, F1W (WAB, WCN)

(ii) Int Cl (Edition 5 ) F03B, F04B

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASE: WPI

Search Examiner

C B VOSPER

Date of Search

2 JULY 1993

Documents considered relevant following a search in respect of claims

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
Y	GB 2166498 A (WAVE) - whole document - shows base struture, floating structure and pump operated by relative movement therebetween	1
X	GB 2062130 A (SALTER) - Figures 2 and 3 and page 1 lines 69 et seq	1,2,4 and 5
X	GB 2007314 A (BRITISH) - whole document	1,2 and 4
X	GB 1596053 (DEFENSE) - Figures 6 to 9 and page 3 line 32 et seq	1, 2
Y	GB 865696 (STUCHLY) - Drawing and page 2 line 70 et seq - typical example showing bellows pump	1
Y	US 3970415 (WIDECRANTZ et al) - whole document - shows pump operated by relative movement between fixed and floating structures	1
X	US 3961863 (HOOPER) - whole document	1, 2
X	SU 1153104 (PETROZAVOD) - drawings	1 to 3

Category	Identity of document and relevant passages	Relevant to claim(s)

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E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

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